Using the 5E Instructional Model to View Geospatial Technology Use in K-12 Classrooms

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Abstract

The 5E Instructional Model, developed by the Biological Sciences Curriculum Study, provides a useful framework for designing, developing, and implementing lesson plans and curriculum materials. Further, the 5E Instructional Model is well grounded in the research of instructional theorists and provides a framework for which to build knowledge and skills in the next generation of problem solvers. The author uses this model as a framework for investigating content and pedagogy of geospatial technology (GST) instruction in K-12 classrooms. Exemplary lessons using GST are provided to highlight each of the 5 sequential 5E phases and to show the cross-curricular nature of GST against a backdrop of the national science standards. Currently the use of GST in K-12 curricula is limited, while the use of GST in business and in the lives of people worldwide continues to expand. Accordingly, the author contends that the influence of the 5E Instructional Model on supporting the logical progression of learning can be harnessed to assist in closing the gap between societal use of GST and instruction with GST in K-12 schools.

Keywords: geospatial technologies, GST, 5E instructional model, K-12, instructional theory

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Informed by contemporary research on student learning, the Biological Sciences Curriculum Study (BSCS) developed the 5E Instructional Model—hereafter referred to as the BSCS 5E Model—to serve as a driver of learning and innovation in classrooms across the nation. The BSCS 5E Model has five successive phases with unique instructional emphases: engagement, exploration, explanation, elaboration, and evaluation. Together, these five phases comprise an instructional sequence that encourages students to work through problem-solving situations as actively engaged learners. This model provides a useful framework for designing, developing, and implementing lesson plans and curriculum materials. Thus, it is the author’s contention that this framework could be useful for investigating an area in need of research: content and pedagogy of geospatial technology (GST) instruction in K-12 classrooms. This article uses the BSCS 5E Model to reveal how GST can be incorporated into K-12 curricula. The importance of this technology is underscored with five exemplary lessons, each developed with the aim of accentuating one of the five phases of the BSCS 5E Model.

GST is “an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the graphic, temporal, and spatial context” (National Research Council, 2006). GST includes three distinct branches of technology that all relate to mapping, measuring, and analyzing phenomena that occur on Earth: geographic information systems (GIS), global positioning systems (GPS), and remote sensing (RS). Each GST branch has unique applications for various spatial contexts and
can function independently or in concert to reveal more in-depth spatial relationships. The ultimate use of GST revolves around problem solving within contexts of spatial orientation.

The demand for persons with geospatial skills has grown rapidly in the 21st century. This unprecedented growth of GST in recent years suggests a need for educational institutions to incorporate this emergent technology in the curricula of K-12 classrooms across the country. The United States Department of Labor Statistics (2006) predicted strong growth of GST by 2014. In the 2006 Occupational Outlook Handbook, the Bureau of Labor Statistics foreshadowed a growth rate of slightly higher than 50% from 2004 to 2014, specifically in the Network Systems and Data Communication Analysts category. These auspicious predictions about the eminent growth rate for GST, coupled with an estimated 600% market increase (5 to 30 billion) from 2002 to 2005, provide an optimistic outlook for jobs in the field of GST.

Kerski (2003) asserted that schools lag behind society in the use of GST, stating that “the state of the art is far beyond the state of practice. . . . Only three percent of schools in the United States are effectively integrating technology into all aspects of their educational programs” (p. 129). However, GST is capable of being infused into science curricula, allowing students to view myriad topics such as wetlands, forests, sedimentation, weather, pollution, and radon levels. Curriculum reform involving GST at the K-12 level may fundamentally change students’ spatial thinking and problem solving abilities—leading to and resulting from increased provision of opportunities to solve “real-world” problems.

The National Research Council (NRC, 2006) supported the inclusion of GST in K-12 education. In a recent report, the NRC (2006) indicated that flexibility, spatial thinking, and a skillset commensurate with lifelong learning are key proficiencies that K-12 graduates must possess. The demands for workers with these proficiencies, especially spatial thinking skills, are central to the current focus on and importance of information technology (IT). The escalating use of GST in society, NRC’s (2006) call for an inclusion of related competencies, and the optimistic outlook furnished by the United States Department of Labor all signal the potential benefits of incorporating GST in K-12 classrooms across the nation.

GST Content and Pedagogy

The BSCS 5E Model consists of five sequential phases: engagement, exploration, explanation, elaboration, and evaluation (see Figure 1). Elements of the BSCS 5E Model can be traced back to the works of Johann Herbart in the early 20th century. His work was based on using students’ prior experiences, as well as their current knowledge, which can be seen in the engagement phase. Further, elements of John Dewey’s teaching models can be seen in the elaboration and evaluation phases of the BSCS 5E Model. The clear reflection of these theorists’ ideals in the BSCS 5E Model attests to the sound theoretical framework from which it was built. The model began in the 1960s as three phases (i.e., exploration, invention, and discovery) and the BSCS added engagement and evaluation at the beginning and at the end of the original three phases, respectively. The BSCS 5E Model has been used in biology and integrated science programs since the 1980s (Bybee et al., 2006). In the following sections, a brief description of each of the five sequential phases of the BSCS 5E Model will be provided, followed by specific exemplar lessons that highlight each respective phase.
Engagement

The engagement phase of the BSCS 5E Model involves eliciting the students’ attention to the tasks, concepts, or skills included in the given lesson. The instructor or lesson should focus on connecting the new lesson with students’ prior knowledge, while also providing activities that pique the interest of students and educe learner engagement. This phase should serve to link past learning experiences with new learning outcomes in an organized and meaningful way (Bybee et al., 2006).

As an exemplary lesson plan that underscores the importance of the engagement phase, Wigglesworth (2003) conducted a research project to investigate the strategies developed by middle-school students when solving a route-finding problem using ArcView GIS software. In this study—called the Atlanta Bike Route Problem—students were tasked with interviewing managers of movie theaters each weekend to determine the best selling candy at their respective theaters. The students were instructed to create a bicycle route beginning at Bud’s Gas Station, going through four movie theaters, and then ending at the Dream Ice Cream store.

When approaching this problem, many students used the scientific method as a strategy for creating and testing hypotheses in order to discover the shortest route. Prior experience with maps and prior experience with the territory to be traversed were key components that engaged students in this activity. Wigglesworth’s (2003) findings supported tenets of the engagement phase of the BSCS 5E Model, as he found that prior knowledge of maps by the students had a positive influence on their strategies. Further, Wigglesworth’s (2003) arguments supported Mackaness’ (1994) warning to avoid creating students that are experts of the technology despite having little or no spatial awareness; that is, the curriculum should assist students with learning how to use the technology in addition to (not at the expense of) developing the students’ spatial awareness and spatial abilities. In the Atlanta Bike Route Problem, students’
background knowledge of maps were used to engage their understanding. Using background knowledge is not a new discovery in education and is used by experienced teachers to create a climate of effective instruction.

The Atlanta Bike Route Problem is a good example of how the engagement phase of the BSCS 5E Model is supposed to attract student interest. The task creates a need for students to learn GIS software in order to succeed, and does so by including engaging elements from their personal life (e.g., navigating their neighborhoods). Moreover, students’ prior knowledge and experiences (e.g., with maps and the territory) were used to engage the students in the learning process. This study suggests that, before engaging in activities that involve GST, teachers should organize instruction so that it will assist students in clearly understanding relevant knowledge and skills through the use of discussions, assigned readings, and activities (Wigglesworth, 2006).

Exploration

The exploration phase of the BSCS 5E Model typically involves providing students with a common set of activities in order to encourage them to focus energies on the identification and development of various concepts, processes, and skills. The instructor facilitates the process and creates a challenging, learning-enriched environment. Further, the instructor encourages the students to explore this environment with confidence and without apprehension. Problem solving is promoted and students approach lesson plans as opportunities for growth. As with the engagement phase, it is important that these activities link students’ prior knowledge and experience with idea generation and problem solving (Bybee et al., 2006).

In a study conducted by Doering and Veletsianos (2007), middle-school students used GST to explore an online program called GoNorth! Exploring real-world issues collaboratively with scientists in the field is central to the theme of GoNorth! The collaborative learning process was emphasized in this exploration activity. When students began this unit, they initially explored the world with Google Earth. The first sites that students studied were their homes and their neighborhoods, and the location of each in relation to other landmarks. Doering and Veletsianos (2007) quoted one student as saying, “I never knew my home was so close to the river” (p. 221). Other examples of student responses include statements regarding where they shopped and comparisons about how similar the roof of one’s house was to another. Part of a lesson on climate mapping involved students gathering data, creating GST snow cover maps, and comparing snow depth with average temperature and elevation. Using this information, students were then able to predict where they could encounter various levels of snow depth, thus providing them with experience exploring a real-world application of GST. The exploration of map layers with GST allowed these students to view their world through a different perspective. The study by Doering and Veletsianos (2007) illustrated some essential aspects of the exploration phase that are promoted by the BSCS 5E Model. GST promoted students’ active engagement in the exploration of their community, as well as the exploration of distant locations. It was evident that quality learning occurred as a result of (a) instruction that fostered high levels of exploration by students and (b) data-driven technology that was facilitated by GST. Doering and Veletsianos (2007) concluded that GST offers an opportunity for a generation of students to explore and, ultimately, to learn by using engaging computer software that facilitates an intrinsically gratifying and seemingly effortless flow of learning.

Explanation

The explanation phase of the BSCS 5E Model provides an opportunity for students to demonstrate their knowledge of the concepts, processes, and skills acquired in the engagement and exploration phases. Students may call upon prior knowledge and previous learning experiences—including those that took place in the engagement and exploration phases—to explain or illustrate their understanding of a given concept or skill. This phase is not limited to content covered in the first two phases, as instructors may also introduce and explain new concepts, processes, and skills. Instructors facilitate this phase by providing feedback and additional explanation to students’ knowledge and skill demonstrations. Ensuring that the students leave this phase with a profound understanding of the concepts, processes, and skills covered is a key outcome of this phase of the BSCS 5E Model (Bybee et al., 2006).

Shin (2006) conducted research that investigated the impact of GST on students’ learning outcomes in geography. The research was designed to use pre-designed modules to gather data about students’ geographic abilities. This mixed methods research design asked students to draw pre- and post-lesson sketch maps, which permitted comparisons between pre- and post-lesson content knowledge and map skills pertaining to geography. The instructional module had three topics of geographic investigation: the local community, the state, and the nation. Each of these topics focused on specific geographic content knowledge that was matched with specific GIS functions. After being exposed to each of the three topics, students were presented with a historical and geographic inquiry project. The project included geography content knowledge activities where students were expected to create GST maps using the skills learned in previous lessons. As the students progressed through the modules, the targeted GIS technology skills ranged from opening a pre-existing map to using the query function. The inquiry project required students to use the learned skills to explain the appearance of the map.
Instruction that incorporates real-world experiences allows students to apply known quantities in their lives to enrich their overall learning. Indeed, including local geography data put the students’ communities into context and enhanced the extent of students’ understanding (Shin, 2006). Findings from Shin’s (2006) research support the underlying supposition that the inclusion of real-world applications is a key element to increase the efficacy of GST use in K-12 classrooms. A teacher that recognizes this will effectively leverage practical, real-world examples to increase student engagement, exploration, and explanation. The method of explanation exemplified in the present example allowed for deeper understanding by the students and possibly fortified community relationships in the school (Bybee et al., 2006). Shin’s research with fourth-grade students demonstrated that the format of instruction allowed students to explain their thinking as they became engaged in the learning to explore new geographic realities of their own communities.

Elaboration

In the elaboration phase of the BSCS 5E Model, the learning that has taken place during the engagement, exploration, and explanation phases is expanded upon. Students are challenged with new experiences and opportunities that allow them to further their understanding of concepts, processes, and skills. Instructors facilitate this phase by providing students with increased learning opportunities and activities, as well as ample explanation that serves to elaborate on the students’ existing knowledge and skills. In the end, students should develop a broad and deep understanding of important concepts and skills through additional experiences and activities (Bybee et al., 2006).

Keiper (1999) conducted research at an elementary school to examine the impact of GST on geography instruction and learning. The focus of this research was to determine a basis from which to build geography skills with the innovative use of GST. The exemplary lesson plan from Keiper’s study was one that evoked elaboration by having students use GST to create a proposal and supportive rationale for the establishment of a new park in Columbia, Missouri (Keiper, 1999). Each student was challenged to work cooperatively with his or her classmates to develop rationale in support of having a park at a given location in their city. The groups were then asked to elaborate on their rationale in a presentation to various stakeholders, which included a city official. The authentic nature of the project engaged the students in the exploration, explanation, and elaboration of real-world GST applications. The students learned more than just geography, they also developed organizational skills and the ability to reevaluate and reorganize their presentation as the geographic data warranted—namely, they were problem solving (Keiper, 1999). The realistic nature of the presentation and the use of GST software to inform decision making provided an opportunity for the students to elaborate on various concepts relating to community benefit in an authentic, real-world classroom environment.

Evaluation

The final phase in the BSCS 5E Model, evaluation, refers to the students engaging in self-assessments of their learning, of their understanding of important concepts, and of their development of relevant skills. Students assessed the learning that took place during the engagement, exploration, explanation, and elaboration phases. Instructors can facilitate this phase by guiding the evaluative thought processes of the students, as well as provide their own evaluative feedback.

An example of this final phase can be found in the Rural Alliance for Improving Science Education (RAISE) project at Oklahoma State University (OSU), in collaboration with three Oklahoma public school districts. In this partnership, OSU became a major resource for science teaching activities for K-12 schools in Oklahoma (Watkins & Wagler, 2005).

An exemplary lesson plan was the Trash It! student activity, in which participants were given GPS units and two tasks: (a) identify waypoints where litter was found on school grounds and (b) identify waypoints where trash receptacles were located on the school campus. The students were to create a GIS map using the trash data to determine the relationship between the litter and trash receptacle locations. Students then created shapes on a satellite image to illustrate buffers from each receptacle. All of this information was contained on the image and the students quickly identified the problem, as the location of the litter was in disaccord with the locations of the trash receptacles (Watkins & Wagler, 2005). Each student was asked to evaluate the map and receptacle locations and propose new locations for trash receptacles. The students justified their new location using the maps they created.

Watkins and Wagler (2005) reported that, as the group discussion unfolded, students stated how far they would walk to put trash in the receptacles during the recess period. It was determined that 15.25 meters was the distance students agreed to walk to dispose of trash. Finally, students made a proposal to the school principal to move trash receptacles to align more closely with the trash data they collected. The students were excited about using GST to make a positive impact on their real-world, local environment (Watkins & Wagler, 2005).

The Trash It! activity allowed students to evaluate their work as they discussed reasonable solutions to the trash problem on the playground of their school. Their project incorporated all three forms of GTS: GPS, GIS, and RS.
Through the process of real-world application of these technologies, students were able to problem solve a local issue through engagement, exploration, explanation, elaboration, and evaluation; and teachers were able to facilitate the process and enhance the learning process for the students.

**Conclusion**

The GST examples highlighted in this article were not intended to demonstrate or provide empirical evidence for improved student test scores. Rather, the author’s intention was to provide examples that underscore how the BSCS 5E Model can influence student learning in the context of GST lessons and activities. GST is a practical, value-added dimension that a paucity of schools incorporate into their curricula. These connections to the real world add to the practicality and utility of learning, and instructional practices should be implemented accordingly. Barriers to teaching with GST exist, but they are minimal compared to the gap that is present between the societal demand for GST knowledge and what students are currently being taught in schools. It is the author’s contention that educators should make every effort to reduce the technology divide between instruction in K–12 schools and the needs presented by our society. The BSCS 5E Model could serve as an important framework for the incorporation of GST into curricula; if students are engaged, if they are exploring, if they are explaining, and if they are elaborating and evaluating, then they are learning.

The BSCS 5E Model provides a well-grounded framework for integrating the instruction of GST into K–12 classrooms across the nation. Effective GST instruction flourishes in school environments where curiosity about the world is supported by real-world activities (Kerski, 2003). Lindsey and Berger (2009), Merrill (2009), and Slavery (2009) supported Kerski’s assertion through their views on the importance of authenticity and experience in educational curricula. Beatty (2009) adds a physiological perspective, “If we can create experiences and environments that work with the brain’s biological systems (chemical, neurological, emotional, etc.), then perhaps the likelihood of meaningful learning will be increased, and our educational system will be improved” (p. 280). While not all of the examples shared in this article are exclusively science lessons, each example fits with various National Science Standards found at the Mid-Continent Research for Education and Learning website (McREL, 2010; see Appendix A). This is indicative of the interdisciplinary transportability of the BSCS 5E Model to other curricular areas. The BSCS 5E Model is a framework to build knowledge and skill in the next generation of problem solvers.

**References**


### Appendix A

**Table 1**

<table>
<thead>
<tr>
<th>5E Phase</th>
<th>National Science Standard</th>
<th>Geospatial Technology Example</th>
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<tbody>
<tr>
<td>Engagement</td>
<td>Standard 12: Understands the nature of scientific inquiry. Level III / Benchmark 3: Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations)</td>
<td>Wigglesworth (2003) conducted a research project to investigate the strategies developed by middle school students to solve a route-finding problem using ArcView GIS software. Many student pairs use a hypothesis and test strategy to find the shortest route in the Atlanta Bike Route Problem.</td>
</tr>
<tr>
<td>Exploration</td>
<td>Standard 1: Understands atmospheric processes and the water cycle. Level III / Benchmark 3: Knows factors that can impact the Earth’s climate. Standard 12: Understands the nature of scientific inquiry. Level III / Benchmark 6: Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data.</td>
<td>Middle school students followed “Team GoNorth! as they traveled with the porcupine caribou herd…” (p. 218). “Students took on the role of a scientist and developed snow cover maps that correlated snow cover depth with average temperature and elevation” (p. 219). They analyzed data collected from Team GoNorth! to come to a decision on the impact of oil exploration. The students created maps using GPS data and ArcExplorer Java Edition for Educators (AEJEE).</td>
</tr>
<tr>
<td>Explanation</td>
<td>Standard 12: Understands the nature of scientific inquiry. Level II / Benchmark 5: Knows that scientists’ explanations about what</td>
<td>Shin (2006) conducted research that attempted to answer the question, “How does the use of GIS technology affect students’ geography learning?” (p. 109). The research was designed to gather data about students’ geographic abilities</td>
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</table>
happens in the world come partly from what they observe (evidence), and partly from how they interpret (inference) their observations. Through the use of pre-designed modules, students were asked to draw pre and post maps of their city and were to explain why the maps appeared the way that they did.

### Elaboration

| Standard 12: Understands the nature of scientific inquiry |
| Level II / Benchmark 2: Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world. |
| Standard 13: Understands the scientific enterprise |
| Level II / Benchmark 3: Knows that scientists and engineers often work in teams to accomplish a task |

Timothy A. Keiper (1999) conducted research at an elementary school. “The purpose of this study was to determine the outcomes of using GIS to teach geography in an elementary school classroom” (p. 47). Students, in groups, were asked to use GIS skills learned to investigate, rationalize and make a presentation to their city leaders recommending the creation of a new park in their community.

### Evaluation

| Standard 12: Understands the nature of scientific inquiry. |
| Level III / Benchmark 3: Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations) |
| Standard 13: Understands the scientific enterprise |
| Level II / Benchmark 3: Knows that scientists and engineers often work in teams to accomplish a task |

In the Trash It! student activity participants were given GPS units and asked to mark waypoints where litter and trash receptacles were found on their school campus. The students then created a GIS map using the trash data and a satellite image of their school grounds. Combining the data students made trash receptacle location recommendations to the school administration.

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